A HIGH FIDELITY DRIVING SIMULATOR AS A TOOL FOR DESIGN AND EVALUATION OF HIGHWAY INFRASTRUCTURE UPGRADES

by

Michael J. Kelly
Senior Research Scientist

And

Suzanne Lassacher
Research Associate

Western Transportation Institute
College of Engineering
Montana State University – Bozeman

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Helena, MT 59620

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PROBLEM STATEMENT

High fidelity driving simulators provide an opportunity to simulate and test drivers' responses to improvements in infrastructure, information and warning messages, and other deployments. The planned deployments on U.S. 191 in the vicinity of Big Sky, Montana are an excellent opportunity for using a simulator for rapid prototyping. For many of the scheduled deployments of curve, ice, and excessive speed warnings, driving simulation would provide a tool to refine the plan for location, visibility, and message sets. WTI proposes to create and test a simulation capability, using our existing simulator, to quickly and inexpensively evaluate these proposed deployments.

BACKGROUND AND OBJECTIVES

Simulation of improvements in transportation vehicles, routing, information sources, and procedures is a time-tested way to "get it right" before committing to a final plan and deployment. In aviation, rapid prototyping of cockpit displays, layouts, and procedures using medium fidelity simulation and inputs from aircrew members is a required step in systems development. The approach is becoming more widely used with marine and railroad engine control/display development. It is also widely employed in the design of user interfaces to complex software systems.

Computer simulation and rapid prototyping of highway transportation system upgrades and improvements is not a unique approach. Computer-based visualization has been used to provide demonstrations for construction projects. Highly realistic images are computer-generated of a proposed roadway, bridge, or other structure. These are usually still photos although applications of virtual reality systems are increasingly used. The images are typically used to demonstrate to stakeholders how a proposed road or structure will appear. In some cases, the computer-generated photos are used to evaluate potential line of sight, visibility and safety of intersection configurations and other elements.

Approaches using an interactive driving simulator for prototyping and evaluation of large projects have been attempted and found successful. During construction of the Boston Central Artery project, for example, a potential problem was perceived with the location of routing and exit signs in the low ceilings, curves, and grade changes of the tunnels. The University of Massachusetts was contracted to use a driving simulator to simulate the tunnels and evaluate whether the signs could be seen and used. In the evaluation, it was discovered that some of the signs had to be relocated because they could not be seen and read in time for the driver to safely move into the exit lane. A similar approach was then used to evaluate routing signs above ground in the vicinity of Logan International Airport.

This approach is only superficially related to computer-based traffic modeling. In the traffic modeling approach, a traffic network with defined boundaries is identified. Mathematical algorithms describing characteristics of the expected flow are selected. Then characteristics of the traffic stream (if macro-level modeling) or of individual vehicles (if micro-level modeling) are entered into the data base. The model is then run to develop estimates of performance of the traffic network under the defined conditions. All vehicle or traffic behavior is the result of mathematical algorithms serving as estimates of individual driver or traffic behavior. In the simulation approach, human drivers are used in the simulation and their actual driving performance and behavior provides the data. After completing their drives, they can also be surveyed about their reactions and responses to the deployment.

Development of testing scenarios on the WTI driving simulator is a straightforward task. First the roadways, environmental conditions (daytime/nighttime, weather, coefficient of friction), traffic conditions, and natural and cultural features are defined. Tiles representing the basic roadway and terrain are selected and assembled. The programmer then selects from a large library of buildings, vegetation, vehicles, pedestrians, animals and other such entities. These are inserted onto the tiles using a “drag and drop” process. For moving entities, their speed and path is defined. The environmental conditions are entered. Performance measures (up to 48 measures) are chosen.

Using the generic tiles supplied to all purchasers, it is possible to create a roadway containing most of the features needed for testing. For example, WTI created a representation of the roadway over Bozeman Pass on I-90 to test the effects of animal warning signs of vehicle speed and driver alertness. While existing tiles represent generic terrain, the simulator manufacturer can create custom tiles duplicating specific roadways for testing. These can be used to duplicate specific roadway geometries and configurations for rapid prototype testing of proposed deployments.

WTI proposes to employ a rapid prototyping approach, using the Driving Simulation Laboratory and custom tiles representing sections of U.S. 191, to help MDT develop and refine safety countermeasures for that roadway. Use of the rapid prototyping approach will allow MDT to evaluate the impact on driver behavior and refine the deployment placement, measures, messages, and other aspects. With MDT advice, WTI will fund, specify, and obtain custom tiles and entities representing appropriate sections of U.S. 191. Projected safety-related system deployments will be electronically simulated on these tiles. A sample of drivers will then drive through the scenarios to test the effectiveness of deployments. If changes in the systems are suggested, the simulation can be easily altered to represent the new specifications and the refinements evaluated.

BENEFITS

The primary benefit of the visualization and rapid prototyping approach is that it provides an opportunity to “get it right” at an early stage in the design and evaluation process before significant resources are invested in the deployment. The proposed system and its operation are all produced by computer graphics for a very small fraction of the cost of the actual deployment. Changes at this point may involve only a “click and drag” operation on a computer interface, changing one image for another, or rewriting a few lines of code. By simulating the deployment and evaluating and refining it early in the design process, considerable time and money can be saved if changes need to be made to achieve the desired traffic objectives.

RESEARCH PLAN

Task A. Project Management

The initial task is management and coordination of the project including financial management, technical tracking and reporting.

Task B. Develop Tiles and Scenarios Specific to U.S. 191

This task will be funded and conducted entirely by WTI with MDT advice. The specific area of U.S. 191 to receive safety countermeasures will be defined. Relevant natural and cultural features that influence driver behavior on that section of highway will be identified. The simulator manufacturer, DriveSafety, Inc., will be provided with topographic maps in sufficient detail to allow reproduction in custom simulator tiles. WTI will supervise the contractor to assure accuracy and quality of the tiles and the realism and quality of any safety countermeasures that are added to the “entity” menu.

Task C. Evaluate Driver Performance and Behavior

Task C will use scenarios developed using the custom tiles to simulate potential ITS deployments and to obtain data on a sample of drivers who drive on the simulated roadway. Situations conducive to accidents will be simulated and measures related to safety, vehicle control, will be made. A sample of approximately 35 drivers representing a mix of genders and ages will be recruited to represent the typical driving population of U.S. 191. These participants will drive a series of tests involving potential safety enhancements to the highway. They will also complete a written survey or interview about their reactions to the enhancements.

Task D. Validate Driver Performance Data

Task D will compare driver performance data collected in the simulator with available data from the selected roadway. Some data on speed studies already exists. WTI will compare simulator speed data with existing numbers. Comparison of the simulator data with the actual traffic data, whenever possible, will allow WTI to validate results of our prototyping studies and to determine ways to increase the accuracy of our projections.

DELIVERABLES (PRODUCTS)

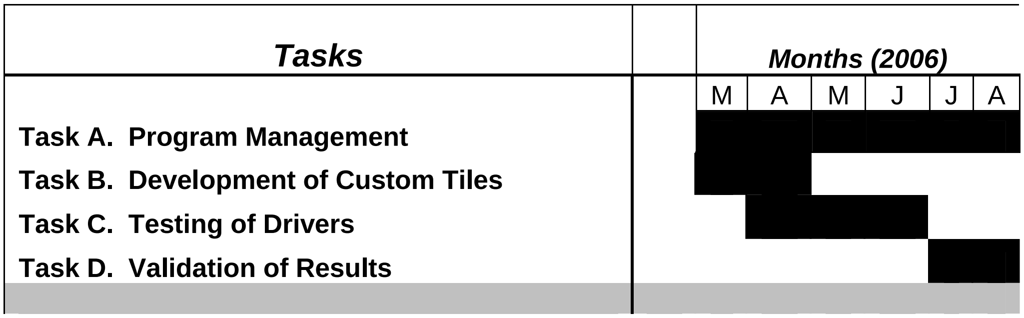
Deliverables will be the following:

Interim Final Report at the conclusion of Task C (4 months after start).

Final Report at conclusion of Task D (6 months after start).

Quarterly progress report (3 months after start).

SCHEDULE


Tasks
Months (2006)
M
A
M
J
J
A
Task A. Program Management
Task B. Development of Custom Tiles
Task C. Testing of Drivers
Task D. Validation of Results

STAFFING

Michael J. Kelly is a Senior Research Scientist at WTI. A senior human factors engineer and project manager, he has more than 30 years of post-doctoral experience managing, directing and performing human factors research and development on advanced transportation systems, communication systems and centers, aviation systems and industrial facilities. He has managed a simulation laboratory used to design and validate helicopter cockpit systems and procedures. He has managed interdisciplinary programs related to advanced transportation systems funded for as much as $5.2 million. He led the effort to create a high fidelity driving simulation laboratory at WTI, which allows testing of driver performance, behavior, and safety in response to custom-designed road and traffic scenarios. Using the Laboratory, Dr. Kelly designs and directs exploratory research (including data collection and analysis) on new prototype devices to improve driver safety, including current studies of driver distraction by drivers using cell phones, effects of alternative warning signs on drivers' behavior during animal/vehicle conflicts, correlations between vision and visual attention with driving safety, and use of advanced technologies to eliminate run-off-road crashes.

Suzanne Lassacher is a Research Associate and Information Technology Manager at WTI. She manages operations of and conducts research in WTI's Driving Simulation Laboratory, which allows testing of driver performance, behavior, and safety in response to custom-designed road and traffic scenarios. During simulation studies, she directs scenario development through selection and placement of simulation tiles and populating those tiles with selected traffic control devices, natural and man-made objects, and tracks and motions of other vehicles. Ms. Lassacher also is the Principal Investigator for the Transportation Research, Applications and Instrumentation Laboratory (TRAIL) project, which will demonstrate and evaluate various data acquisition, control systems, information delivery, and management systems in a small urban and rural environment. She holds a Master's degree in Computer Science from Montana State University.

FACILITIES

Driving Simulation Laboratory: WTI's Human Factors Group is supported by a state-of-the-art driving simulation laboratory. This high-fidelity facility allows testing of driver performance and behavior in a variety of customized scenarios

The DriveSafety DS500C Vection simulator features five visual channels providing approximately 140-degrees of view plus rear-view and side mirrors. The driving cab was once a real 1996 Saturn sedan. It contains the driver seat and still fully functional displays and controls. Instead of being connected to the engine, wheels, and brakes, the controls are now connected to the computer. You still need to turn on the key and buckle up before you can start a drive.

A network of five graphics computers generates the out-of-the-window views seen and the sounds heard by the driver through five speakers. A sixth computer coordinates the five scene generators, converts the driver's control actions into realistic vehicle responses using accurate vehicle dynamics models, and generates the driving scenarios specified by the researcher.

The visual simulation allows the driver to drive through scenarios that include roadways, buildings, traffic signs and signals, other vehicles, trees, rain, snow, fog, and even animals in the roadway. Auditory displays provide a realistic sound environment, including engine noise, wind, traffic, sirens, tire screeches and horns, and any other sounds the user wants to enter. An automated performance measurement system collects a broad range of data on the driver's control inputs and performance.

The simulator operator station allows the researcher to develop and control research scenarios. With this station the researcher can design and implement a custom driving environment through the use of "tiles". Each "tile" represents an assortment of freeways and freeway junctions, different types of surface streets and intersections, and a wide variety of environmental models. Researchers can implement ambient traffic, which can drive autonomously or follow scripting provided by the programmer. With the use of "Virtual Triggers" behaviors of vehicles, pedestrians, animals, etc. can be programmed to follow any behavior as deemed appropriate by the programmer. A set of generic tiles is delivered with the simulator. If tiles that are more specific to a particular roadway are needed, these can be custom developed by the manufacturer through the use of topographic maps.

Some specific research projects that are being pursued via the driving simulator include the following:

- Driver distraction (e.g., with mobile phones) as a major cause of accidents.
- Driver understanding of dynamic messaging systems.
- Aging related deficits in driving performance.
- Winter driving performance and weather warning systems.
- Computer-based systems to assist driving performance.
- Driver behavior and safety in the rural versus urban environment.
- Driver behavior when encountering obstacles such as large animals.
- Young driver education programs in conjunction with the Cold Regions Test bed at Lewistown Airport.
- Active lane delineation technology product testing.

PROJECT BUDGET

Budget		WTI Team				Other Direct Expenses			Totals
		Mike Kelly	Suzy Lassacher	Undergrad (2yrs exp)	Total Hours/Total Costs	Simulator Maintenance	Operations/Communications	Participant Support	Total Costs
Task #	Task Title	$74.72	$31.14						
1	Project Management	10			10				
		$747.20	$0.00		$2,793.12		$ 200.00		$2,993.12
2	Develop Scenario Tiles								
		$0.00	$0.00						$0.00
3	Evaluate Driver Performance	150	160		310				
		$11,208.00	$4,982.40		$17,821.52	$ 1,250.00		$ 700.00	$19,771.52
4	Validate Simulation Results	30	20		50				
		$2,241.60	$622.80		$4,495.52				$4,495.52
	TOTAL HOURS	190	180		370				
	TOTAL DIRECT COSTS (includes ben.)	$14,197.00	$5,605.00		$19,802.00	$ 1,250.00	$ 200.00	$ 700.00	$21,952.00
	Indirect Costs at 20%	$2,839.40	$1,121.00		$3,960.00	$250.00	$40.00	$0.00	$4,250.00
	Total Project Costs	$17,036.40	$6,726.00		$23,762.00	$ 1,500.00	$ 240.00	$ 700.00	$26,202.00

Cost Sharing; WTI will cover the costs of Task 2, Development of Tiles and Entities at an estimated cost of $22,000. In addition WTI will charge the reduced overhead rate of 20%.

Budget by Federal Fiscal Year

Federal FY	Labor Hours	Labor Dollars	Operations/ Commun	Simulator Maintenance	Participant Support	Overhead	Total Cost
2006	370	$19,802	$200	$1250	$700	$4250	$26,202

Budget by State Fiscal Year

State FY	Labor Hours	Labor Dollars	Ops/ Commun	Simulator Maintenance	Participant Support	Overhead	Total Cost
2006	320	$15,307	$200	$1,250	$700	$3,351	$20,808
2007	50	$4,495				$899	$5,394

APPENDIX

Resumes for the following key personnel are attached:

Michael J. Kelly, Ph.D.
Suzanne Lassacher

MICHAEL J. KELLY, PH.D.

Senior Research Scientist, Western Transportation Institute
Montana State University, Bozeman, MT 59717-4250
406-994-6010 (Phone); 406-994-1697 (Fax)

EDUCATION

Ph.D.; Experimental Psychology (Engineering Psychology)	Johns Hopkins University	1975
M.S.; Applied Psychology	Montana State University	1972
B.S.; Psychology	Montana State University	1970

EMPLOYMENT SUMMARY

A senior human factors engineer and project manager with 30 years of post-doctoral experience managing, directing and performing human factors research and development on advanced transportation systems, communication systems and centers, aviation systems and industrial facilities. A proponent and practitioner of the user-centered design process including documented function and task analyses, human interface requirements definition, rapid prototyping and usability testing of candidate user interfaces, and continuing test and evaluation throughout the design and implementation process. Has managed interdisciplinary programs related to advanced transportation systems funded for as much as $5.2 million.

A Senior Research Scientist at the Western Transportation Institute, Montana State University, Dr. Kelly serves as Principal Investigator for research implementing and conducting research in WTI's high-fidelity Driving Simulation Laboratory. He served as Principal Investigator on a driving simulator study of driver distraction while using a cell phone to interface with the 511 travel information system, Task Lead for a driving simulator evaluation of the effects on driver behavior of various animal crossing warning sign configurations, Task Lead on a study of visual and visual attention deficits in older drivers and their effect on driving safety, and Task Lead on a study of ITS approaches to reducing run-off-road collisions. Principal Investigator on an evaluation of the safety benefits of an advanced defensive driving workshop for young teen-aged drivers in which drivers were recruited from their high schools and presented with an intensive one-day workshop. Principal Investigator of a series of research projects exploring applications of information technology to tourism information systems for advanced alternative transportation vehicles in the national parks. Principal Investigator for usability testing and field evaluation of information kiosks for the Lewis and Clark Trail Bicentennial. Principal Investigator for a project exploring applications of intelligent transportation systems in rural northern California. Supports implementation of the Bozeman Transportation Research, Applications and Instrumentation Laboratory (Bozeman TRAIL) which instrumented a major suburban traffic corridor and transmits traffic and road condition data to the TRAIL center at WTI. Mentors junior staff in research methods. Directs undergraduate and graduate student research. Taught a senior level engineering class in multidisciplinary design and a graduate level class in Human Factors in Engineering Design.

As a Principal Consultant, M.J. Kelly and Associates, Bozeman, Montana, Dr. Kelly provides human factors evaluation, recommendations, training, and forensic services. Served as consultant to University of North Carolina and North Carolina DOT during design of the CARAT transportation management system in Charlotte, NC. Provided guest lectures on human factors in advanced transportation systems for FHWA workshops at the California Polytechnic Institute at San Luis Obispo. Provided guest lectures for Georgia Institute of Technology, Auburn University, and others in continuing education workshops on human factors and on advanced transportation systems. Provides forensic consulting and expert witness services related to the design and safety of consumer and industrial products.

As a Principal Research Scientist. Georgia Institute of Technology, Dr. Kelly served as Head of the Human Factors Branch, Electronic Systems Laboratory of the Georgia Tech Research Institute. He was responsible for technical, financial, and administrative management of a group of twelve human factors and transportation professionals and support staff. The Human Factors Branch performed contract research in transportation systems, advanced cockpit design, computer system requirements and usability, communication center design and automation, product and system evaluation, and simulation. Dr. Kelly supported or served as a Task Lead on design projects for cockpits of two military helicopters. Dr. Kelly served as Principal Investigator on a six-year, $5.2 million study of human factors issues in the design and operation of advanced traffic management systems.

PUBLICATIONS

Dr. Kelly has authored or coauthored approximately 70 publications, technical reports, and presentations related to human factors issues in system design, evaluation, or operation. A sample of these is summarized below:

Driver Performance While Interacting with the 511 Travel Information System in Urban and Rural Traffic. Proceedings of the Third International Symposium on Driver Assessment, Training, and Vehicle Design. Iowa City: University of Iowa. June 2005 With L.M. Stanley and S. Lassacher.

Evaluation of the Lewis and Clark Travel and Information Kiosk. Final report to the Information Technology Office, University of Montana. December, 2003. With A. Kenefick.

User requirements for information systems to support alternative vehicles in the National Parks. Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting. Santa Monica: Human Factors and Ergonomics Society. October 2003. With J. Moore.

Preliminary Human Factors Design Guidelines for Traffic Management Centers. (FHWA-JPO-99- 042.) Washington, DC: Department of Transportation. July 1999.

"Advanced Traffic Management Systems," in T. Dingus and W. Barfield (Eds.) Human Factors in Intelligent Transportation Systems, Hillsdale, NJ: L. Erlbaum Associates, October 1997, with D. Folds.

Automation Issues in ITS-Level Traffic Management Centers. In W. Karwowski (ed.) Human Aspects of Advanced Manufacturing and Hybrid Automation. August 1996.

"Performance Measurement during Simulated Air-to-Air Combat," Human Factors, 30, 495-506, 1988.

"Night in the Cockpit," Flying, 111-2, 88-89, 1984.

"Your Biological Clocks: Fatigue and Jet Lag in Air Transport Operations," Thousand Oaks, CA: Vreuls Research Corporation, 1984, with D. Damos and H. Orlady.

SUZANNE LASSACHER

Research Associate, Western Transportation Institute
Montana State University, Bozeman, MT 59717-4250
406-994-6010 (Phone); 406-994-1697 (Fax)

Education

2002 M.S., Computer Science, Montana State University, Bozeman, MT
1990 B.A. Italian, minor Humanities, Florida State University, Tallahassee, FL; Universita` di Firenze, Florence, Italy

Key Qualifications

Ms. Lassacher is responsible for systems administration at the Western Transportation Institute (WTI). She assists other principal investigators with ITS equipment selection, communications, evaluation, and deployment for projects that having ITS components. In addition, Ms. Lassacher is the PI on the Transportation Research Applications and Instrumentation Lab (TRAIL) and the Co-PI on a project that is developing a TMC ConOps for a traffic management center for the Montana Department of Transportation (MDT). She is also the Driving Simulation Laboratory Manager. Ms. Lassacher has seven years experience in computer programming and systems administration.

Experience

Driving Simulator Lab. Ms. Lassacher is responsible for setting up and maintaining the driving simulator lab. She currently manages the lab. She is responsible for seven computers running two different operating systems, networking, and systems administration and other hardware troubleshooting and maintenance. She directs development of scenarios by selecting and joining appropriate roadway tiles, selecting and placing “entities” on the tiles, modeling movement and changes in the entities, and setting up performance measurement. She is responsible for all interactions with the manufacturer for the development of custom capabilities, entities and tiles.

> **Evaluation of Driver Distraction.** Ms. Lassacher created the simulated training and testing scenarios used in this study. She determined the requirements of the study and created appropriate scenarios to test for various conditions and situations commonly encountered by drivers.
>
> **Bozeman Pass ITS Evaluation.** Ms. Lassacher is directing the portion of this project that involves the use of the driving simulator. She is responsible for working with the PI and the stakeholders to determine the number of scenarios needed and other related requirements. After all requirements have been determined, she will program the scenarios, run pilot tests, and oversee the recruitment, training, and testing of the subjects. Data will be collected and analyzed for the principal investigator for use in the study.
>
> **Auditory and Haptic Warnings for Run-Off-Road Incidents.** Ms. Lassacher is working with the simulator manufacturer and an outside vendor to develop and install a custom warning system system based on vibratory cues in the simulator seat.

Transportation Research Applications and Instrumentation Lab (TRAIL). Ms. Lassacher is Principal Investigator for this project. The goal of this project is to develop a virtual traffic management center that can be used for data collection, analysis, and archiving as well as a tool for students and professionals to receive hands-on experience with traffic technologies. Ms. Lassacher researched several ITS technologies and communications strategies prior to selecting the in-pavement sensors and communication scheme used in the project. She visited traffic management centers in Oregon, California, Texas, and Utah to research ITS technologies and communications schemes currently being used. Ms. Lassacher worked with the Montana Department of Transportation and the City of Bozeman to deploy in-pavement sensors at seven key intersections in Bozeman, MT. The sensors collect information on vehicle speed, vehicle classification, volume, and road pavement conditions consisting of pavement temperature, wet/dry status, and percentage of anti-icing solution present on the roadway. The sensors transmit the collected data wirelessly to a 915 MHz radio frequency module housed in the local base unit attached to the traffic signal mast. The collected data is then transmitted wirelessly via a Spectra wireless modem and an omni directional 2.45GHz antenna to the local base unit in its line of sight until it reaches the master base unit where the data is stored in an RPU until it is downloaded via an RS 422 serial connection for analysis.

Concept of Operations for a Rural Traffic Management Center for MDT. Ms. Lassacher is Co-Principal Investigator on this project which entails developing a concept of operations for a rural traffic management center for Montana Department of Transportation. Her experience with the TRAIL lab and her research on traffic management centers and communications schemes will be utilized in developing viable options for the MDT traffic management center.

Evaluating Accuracy of RWIS Sensors. Ms Lassacher was involved with setting up wireless communications between a camera that will be deployed on Bozeman Pass and the laptop that will be used for downloading the data collected in the field.

Video Recorder for Trailers. Ms. Lassacher was responsible for setting up a digital video recorder and data retrieval from said recorder that resides in a trailer deployed in strategic locations in California.

Past and Present Professional Affiliations

Association of Women in Computing (AWC)
Institute of Transportation Engineers (ITE)